International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 7 Issue 3, May-June 2023 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Hydrogeological Investigation for Aquifer within Oyo Federal Constituency, Southwestern Nigeria

Oladejo, O. P.[1]; Amusat, T. A.[2]; Ogunkoya, C. O.[3]; Akinlabi, I. A.[4]; Olafisoye, E. R.[5]

[1,2]Department of Physics, Emmanuel Alayande University of Education, Oyo State, Nigeria
[3]Department of Physics, Ajayi Crowther University, Oyo Town, Oyo State, Nigeria
[4]Department of Earth Sciences, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[5]Department of Physical Sciences, Olusegun Agagu University of Science and Technology, Ondo State, Nigeria

ABSTRACT

Electrical resistivity sounding was carried out in four Local Government Areas (LGAs) in Oyo Federal constituency, Oyo state. The geophysical survey was carried out in ten different rural/urban communities/locations in each of the four (LGAs) with the aim of determining the hydrogeology of the study areas for possible identification of aquifers that can serve as possible location of borehole drilling. The potential aquifer investigation was carried out using ABEM terrameter while schlumberger arrangement was the measurement method adopted for the forty Vertical Electrical Sounding (VES) stations in the study areas. Iteration processes using WINRESIST programme was performed on the field data and generated results includes: the thickness, depth and resistivity values of each layers. The geo-electric investigations revealed three and four layers. The results also revealed two categories of aquifers; the High Water Potential (HWP) and Low Water Potential (LWP). The resistivity layers that are less than 400 ohmmeters are categorized with HWP zones (deep aquifers) located at different thirty-five VES stations while Local Water Potential (shallow aquifers) areas are found at five various locations with their resistivity greater than 400 ohmmeter. The aquifers locations can be considered for borehole drillings in the study areas.

KEYWORDS: *Resistivity, Aquifers, Vertical Electrical Soundings, High water potential (HWP), Low water potential (LWP), Local government, Rural community, Schlumberger, Curve type, Oyo-town*

How to cite this paper: Oladejo, O. P. | Amusat, T. A. | Ogunkoya, C. O. | Akinlabi, I. A. | Olafisoye, E. R. "Hydrogeological Investigation for Aquifer within Oyo Federal Constituency, Southwestern Nigeria" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-7 | Issue-3, June 2023, pp.670-683, URL: www.ijtsrd.com/papers/ijtsrd57450.pdf

IJTSRD57450

INTRODUCTION

Geophysics plays important roles for characterizing the groundwater in the hard rocks, it has provide us with various application of geophysical techniques which includes mapping of depth and thickness of aquifers, mapping aquitards or confining layers, locating fractures and fault zones, mapping contamination of groundwater and mapping of saltwater intrusion among others [1]. There are many geophysical techniques that can be used for hydrological exploration, namely; seismic, gravity, magnetic methods and electrical resistivity used in this research.

Electrical resistivity technique is one of the most commonly used method among the geophysical methods for groundwater exploration, simply because of the simplicity of the technique, the resistivity variations for different formations, the changes that occur due to the saturated conditions and are cost-effective ([2], [3], [4], [5])

This technique has been extensively used nowadays in the areas of oil and gas, and hydrogeology. The techniques' basic ideas is to determine the resistivity (fundamental physical property) of any rocks. The measurement of this resistivity is dependent of lithology, porosity, water saturation, and ionic concentration of the pore liquid ([6]). Some rocks are conductor of electricity, when current is passed through subsurface and also to

different layer of rocks, they experience different type of resistance provided in different layers of rocks and hence we determined the potential difference. Two potential electrodes placed on the surface can also determine the voltage. By using the current, voltage, and ohm's law, we can determine the apparent resistivity of the subsurface. Hence the electrode arrangement for electrical resistivity is shown in figure 2.

The Vertical Electrical-resistivity Soundings (VES) is applied whenever a depth section is to be determined. In this method, increase in the depth of investigation can be obtained by gradually increasing the distance between the current electrodes such that current can penetrate deeper into the subsurface and not horizontally (resistivity profiling). The resistivity methods for hydrogeology investigation (Schlumberger configuration) in determining the location of aquifers are exclusively used for depth studies. Many authors have used geophysical tools of resistivity for groundwater exploration ([7], [8], [9], [10], [11], [12], [13], [14], [15]).

Water on earth is an important resource, all habitants need freshwater. About 97.2% of water on earth is confined in the ocean, which is not useful for majority of the habitants because it's a saltwater. A little less than 3% of water on earth (2.8%) is freshwater which constitutes saline lakes, inland seas, soil moisture, stream channels and atmosphere but only about 0.62% of the freshwater (2.8%) are groundwater which are insufficient globally. As the population increases, the pressure on the available groundwater also increases ([16]).

In other to meet the potable water satisfaction, many residents in the study area resulted to digging of wells in their localities ([16]; [17]). However, other major sources of water for various activities in this study area varies from rainwater, inside and outside pipe-borne water, tanker/vendor supply, borehole, dam, and nearby rivers. Over 3% of the population in Oyo and its environs depends on well water for their domestic activities **(**[16]). However the plan for availability of freshwater supply in the study area has become a major challenge. So there is need for groundwater investigation using Schlumberger vertical electrical sounding (VES) in the constituency. The study will be able to determine the possible location of aquifers that can serve the populace in the areas of study, the deployment of Schlumberger vertical electrical sounding (VES) in Oyo constituency would provide the understanding of subsurface hydrology of the area.

STUDY AREA

The study areas include four rural/semi-urban Local government areas of Oyo state which form part of Afijio/OyoEast/OyoWest/Atiba federal constituency. This constituency is one of the 14 federal constituencies in Oyo central senatorial district (figure 1). The constituency is selected for the research based on their high water consumption in the areas due to farming activities (e.g. gari production which is significant to this areas), and population growth. [18] shows that the major sources of water in the study area is either surface water and groundwater which are grossly inadequate.

Afijio is one of the local government of Oyo state with the seat of power located in Jobele town, its estimated population over 182, 755. It covers area of 722km^2 area of land and the major economic activities of the inhabitants is farming. However, vertical electrical soundings (VES) were carried out at different towns and villages in the local government areas, these VES locations are Baynikol, Eleekara, farm settlement, fiditi, Odofin Awe, Oniyere, Akinmorin Jobele, Iware and Imini. The major source of water available in this area is groundwater and its availability is less than 15% [18].

Atiba is one of the local governments in Oyo town having the head-quarter located in Offa-Meta. It has landmass of 1757km^2, the population of this local government is estimated to be over 121,180. The most acceptable occupation in this area is farming. The local government is made up of different towns and villages some of which were used for vertical electrical sounding used in this research work. The VES stations were Oke-Afin, Lagbodoko, Aremo, Odejin, Oke Olola-Aladoota, Omo Oba/Agunpopo, Oke-Ebo, Isale-Oyo, Koso, and Elegbo. Less than 22% of surface water available in this area.

Oyo-east is another local government in this constituency domiciled in Oyo town situated on 144km^2 landmass with the population of over 183,741 inhabitants. The VES location in this local government includes Baara, Ajagba, Alodi, Apaara, Apinni, Balogun, Jabata, Oke-Apo, Oluajo and Araromi which also form part of the towns and villages in Oyo-east. A rich agricultural heritage is the major economy in these areas which has been affected by inadequate water supply. Less that 15% of water is available and the source is majorly surface water

Oyo-west is the fourth local government that constitute Oyo federal constituency and third in Oyo town with it's headquarter located in

Ojongbodu. The population is over 294,812 citizens. It covers an areas of 526 km^2, its economic activities are trading and faming. The locations of the electrical soundings are Akeetan, Oke-Afin, Fasola/Soku, Iseke, Ojongbodu, Osokun, Iyaji, Opapa/Fatuk, Owode and Pakoyi station.

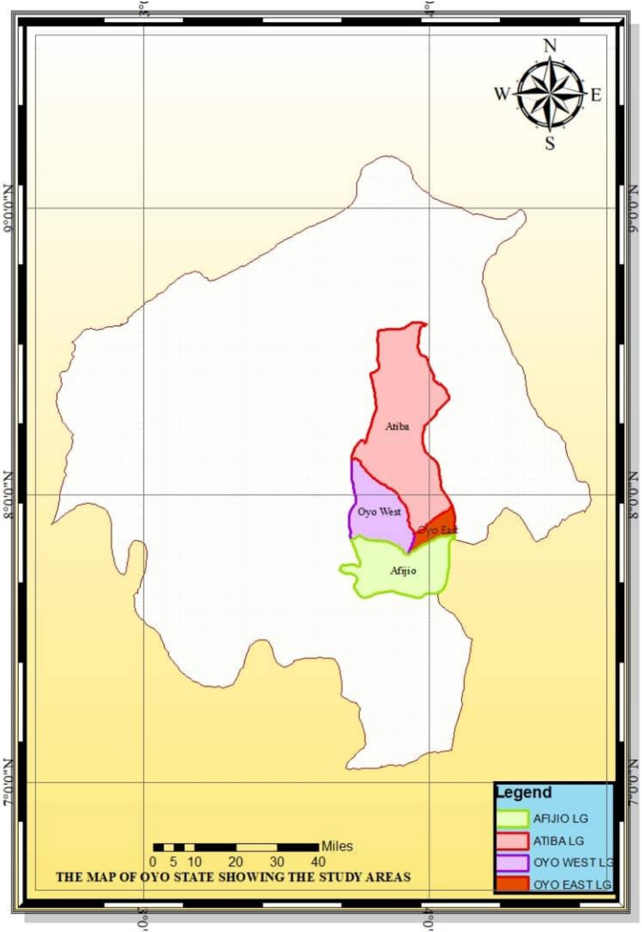

Figure 1: Map of Oyo state showing the showing the study areas

THE GEOLOGY OF THE STUDY AREA

The basement complex of Nigeria lies in the West-Africa craton, Congo craton and Tuareg block. It forms part of Pan African belt and Trans saharan of the Proterozoic age which represents the igneous and metamorphic structural framework consisting the PreCambrian rocks. Geologically, the basement complex of South-west Nigeria which include the study area is made of both major and minor rocks. Migmatites, quart-schist, gabbro among others were the major rock types in the basement complex while minor rocks in the area includes older granite, pegmatite and gneiss ([19] [20]; [21]). The area is underlain by undifferentiated schist, migmatite, magmatic gneiss and quartzite.

MATERIALS METHODOLOGY

The relationship between the current density J and electrical resistivity measured in ohmmeter is given as

$$J = \sigma E = \frac{1}{\rho}$$

$$J = -\nabla . V . \frac{1}{\rho}$$

The Ohm's law for electrodes in semi-sphere of area $2\pi a$

$$J = \frac{1}{2\pi a} = -\frac{1}{\rho} . \frac{dV}{dr}$$

By integration $V(r) = \frac{I.\rho}{2\pi a}$

Where

V = Electric Potential

a = Distance from a point electrode

ρ = Resistivity

I = Current

Electrical resistivity method is one of the methods in geophysical prospecting, its principles involve injecting electrical current into the ground through current electrodes A and B and the measured Potential through the potential electrodes M and N.

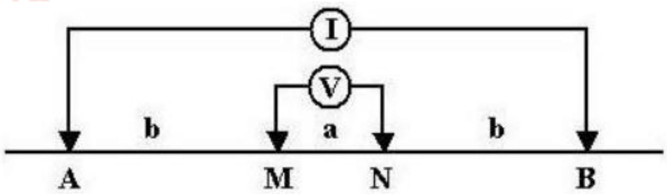

Figure 2: Potential electrode arrangement for electrical resistivity survey

The measurement of current and potential made it possible to calculate apparent resistivity ρ_A of the ground using the equation

$$\rho_A = \frac{2\pi . V_{MN}}{I_{AB}} [(AM)^{-1} - (AN)^{-1} - (MB)^{-1} + (NB)^{-1}]$$

Where

ρ_A = Apparent resistivity measured in Ωm

AM = Distance between current electrodes measured in m

AN = Distance between potential electrodes measured in m

V_{MN} = Potential difference between potential electrodes M and N measured in mV

I_{AB} = Injected electric current between electrode A and B measured in mA

The apparent resistivity ρ_A of the Schlumberger arrangement is given by

$$\rho_A = \frac{\Pi}{4} \left[\frac{AB}{MN}\right] . \left[\frac{V_{MN}}{I_{AB}}\right]$$

The Vertical Electrical Sounding (VES) is a geophysical techniques that allows vertical assessment of subsurface layers through determination of apparent resistivity, depth and thickness values.

In Schlumberger arrangement, a ≪ b. Hence the potential at point M is given as

$$V_M = \frac{\rho_A I}{2\Pi}[(AM)^{-1} - (MB)^{-1}]$$

The potential at point N is given as

$$V_N = \frac{\rho_A I}{2\pi}[(AN)^{-1} - (NB)^{-1}]$$

The potential difference is

$$V_{MN} = V_M - V_N = \frac{\rho_A I}{2\pi}[(AM)^{-1} - (AN)^{-1} - (MB)^{-1} + (NB)^{-1}]$$

$$\rho_A = \frac{V_{MN}}{I}.K$$

$$K = 2\pi[(AM)^{-1} - (AN)^{-1} - (MB)^{-1} + (NB)^{-1}]$$

Where K is the geometric factor that will generate a value for the given electrode spacing.

Electrical resistivity investigation was employed in the study area to determine the groundwater concentration of the area through the measurement of vertical resistivity of the complex geology of the study area. Ten (10) vertical electrical resistivity (VES) were carried out across each of the four (4) local governments that made up Oyo Federal consistency totaling forty (40) VES stations across the study area. The vertical electrical soundings performed generates a deeper measurement of depth as the increase in current electrode separation increases the depth of current penetration that allows deeper depths to be investigated (figure 3).

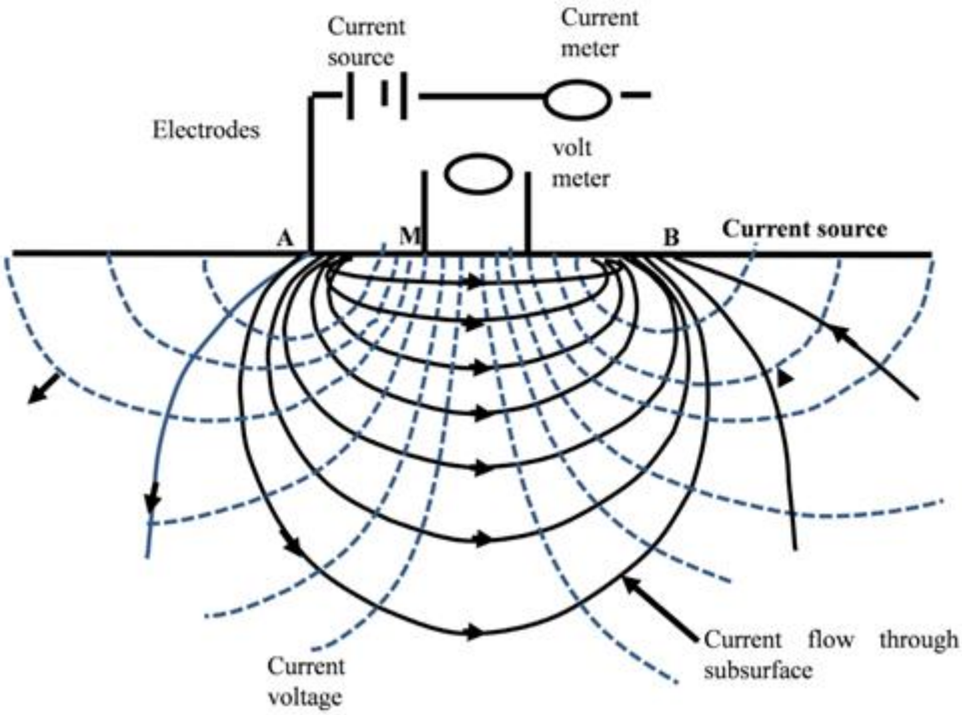

Figure 3: The flow of electric current

Schlumberger electrode arrangement as one of the common electrode arrays suitable for VES were employed with maximum current electrode distance of 120 m. The depth of penetration of this arrangement is 0.125AB [22]. The acquired data (measured field resistance) was converted to apparent resistivity using [23] equation.

$$\rho_a = \frac{\pi L^2 \Delta V}{2lI} \qquad 1$$

l is half potential-electrode spacing $\left(\frac{MN}{2}\right)$, L, the half current-electrode separation $\left(\frac{AB}{2}\right)$, $\frac{\Delta V}{2L}$, surface gradient of potential at the mid-point between M and N, I, the current input.

A graph of apparent resistivity versus current electrode spacing was plotted on bi-log graph for each of the electrical sounding (VES) using computer programming, WinResist version 1.0 (an automative iteration

software employed for iteration and inversion processes). This programming processes were conducted for VES stations 1 to 40 repeatedly until the root mean square error (RMS-error) reduced to minimum (less than 5%). The results of the iteration produces parameters for quantitative interpretation which includes thicknesses, depths and resistivity values for each layers (Table1).Researchers have employed this approach extensively in hydrogeology exploration ([24], [25], [26], [27], [1], [29])

The Curve type is a representation of part of the qualitative interpretation, it also plays important roles in the quantitative interpretation. It can be used to describe how layers changes their resistivity values with depth. The interpretation of VES curve type depends on the number of subsurface layers detected. The three (3) layers curve type in this research are represented as H-type, A-type, Q-type and K-type, while the composite sounding curve type represents layers greater than three (3) such as HK- type, HA-type.

RESULTS AND INTERPRETATION

A total of 40 vertical electrical soundings (VES) were carried out in the study areas constituting the 4 local government areas namely; Atiba, Afijio, Oyo-east and Oyo West local governments. The table 1 displayed the summary of interpreted VES results in the study area.

The electrical resistivity sounding curve of the study areas shows two major distinct layers which were 3-layers (H- and A-type) and dominant 4-layer geo-electric sections (QH, HA, HK- curve type).All the VES locations has 4 geo-electric layers with exception of Fiditi ward II, Odofin Awe ward, in Afijio local government; Omo-Oba/Agunpopo, in Atiba local government; Jabata, and Araromi, in Oyo-east; Akeeta and Owode in Oyo-west; which are made of 3 geo-electric layers.

The subsurface geologic sequence beneath the study area under each VES station is comprises of topsoil, weathered basement, fractured basement and fresh basement. The topsoil is the first layer and it is composed of sandy clay, clay and lateritic soil with resistivity values ranging from 77.4 Ωm to 5365.5 Ωm. Only 12 of the VES stations have topsoil's thickness less than 1 m, the VES stations are Fiditi ward (0.7), Onirere village Awa-ward (0.5), Iware ward (0.9), Aremo (0.6), Omo-Oba/Agunpopo (0.9), Elegbo (0.9), Alodi (0.8), Apinni (0.7), Oke-Apo (0.9), Alu-Ajo (0.6), Akeetan (0.8) and Opapa (0.6). It is however observed that VES stations such as VES 5, 10, 13, 16, 18, 23, 26, 28, 29, 34 and 36 are characterized with high electrical resistivity values ranging from 1660.1 Ωm to 5365.5 Ωm suggesting the lateritic nature of the top soil in these areas.

The underlying layer of the top soil is the weathered layer which is considered as a possible High Water Potential (HWP) Zone otherwise known as aquiferous zones ([30], [31], [32], [22], [33], [34]). Its electrical resistivity is between 44.2 Ωm (Lagbodoko VES station in Atiba area and 4574.1 Ωm (at Baara ward, Oyo-east). This layer consists of clay and sandy clay. [32] also characterized the weathered basement to be water saturated zones and the weathered layer whose thickness is greater than 25 m with low content clay is categorize to be zones of high aquiferous zones. Therefore the weathered layer from the study areas with low values of clay content as indicated by the resistivity (<400 Ωm) in which intergranular flow is dominant are known as High Water Potential (HWP) zones; hence this study has shown the presence of High Water Potential (HWP) zones at different thirty-five (35) VES stations while five (5) VES stations are identified with Lower Water Potential in the study.

In Afijio Local government area, all the VES stations are High Water Potential (HWP) Zones except Baynikol ward with resistivity greater than 400 Ωm (1853.6). The thickness of the HWP in the area varies between 2.6 m and 41.4 m while the depth range from 3.6 m to 41.6 m. The HWP zones in Atiba Local government area are located at Lagbodoko, Aremo, Odejin, Oke-Ololа aladoota, Omo Oba/Agunpopo, Oke-Ebo and Isale Oyo with their resistivity between 44.4 Ωm and 247.7 Ωm, while thickness and depth varies from 2.2 m to 29.0 m and 3.1 m to 30.4 m.

In Oyo-east Local government area, only Baara VES station is identified with Lower Water Potential (LWP) with resistivity 4574.1 Ωm. The thickness and depth of HWP in this Local government varies from 1.3 m (Oluajo) to 15.3 m (Araromi) and 1.9 m (Oluajo) to 27.2 m (Araromi) VES station respectively.

In Oyo-west area, the result of the electrical soundings shows all the VES stations in Oyo-west Local government are identified with the Highest Water Potential (HWP) zone. The first HWP zone is found at Akeetan area with resistivity, thickness and depth to be 301.2 Ωm, 36.9 m and 37.7 m respectively. The last VES station of HWP zone is found at Pakoyi area showing the resistivity, thickness and depth as 234.2 Ωm, 26.9 and 29.5 m respectively.

The third layer is fractured layer but terminated at Fiditi ward II and Odofin Awe ward in Afijio, Omo-Oba/Agunpopo in Atiba, Jabata, Araromi in Oyo-east; Akeetan and Owode in Oyo-west area. The resistivity values of the layer lies between 200.9 Ωm and 13274.0 Ωm, with thickness from 7.1 m to 42.5 m. The resistivity values greater than 1000 Ωm in this layer were attributed to be granite while electrical resistivity values less than 1000 is presumed to be sandy/sandstone materials. The sands are water saturated which generate the dominant layer for groundwater extraction ([35], [36], [37]). The fractured layer is extensively thickest at Iyaji VES station in Oyo-west with resistivity 5568.0 Ωm and thinnest at Eleekan ward with resistivity 1963.1 Ωm. This layer also shows the presence of the Highest Water Potential (HWP) at VES stations Baynikol ward (224.9 Ωm), Aremo Police station (303.6 Ωm with thickness 14.6 m) and Oluajo VES station (200.9 Ωm with 37.6 m thick) with their resistivity less than 400 Ωm.

The last layer with resistivity values ranges between 222.8 Ωm and 6265.7 Ωm with infinite depth were inferred to be fresh/fairlyfresh basement. However, the resistivity around Aremo police station, Isale-oyo, Apaara, Apinni, Akeetan Iseke and Osokun is inferred to be basement sedimentary contact depicted to be an extended layer from the third layer with resistivity values less than 400 Ωm with infinite thickness.

Table 1: Summary of interpreted VES results in Oyo area

Ves No.	Ves Locations	Local Government	No. Of Layers	Apparent Resistivity Values	Probable Lithology	Depth (M)	Thickness (M)	Curve Type
1	Baynikol ward	Afijio	4	198.3 1853.6 224.9 2717.0	T.S W.L F.L F.B	2.0 5.7 26.5 -	2.0 3.7 20.8	QH
2	Eleekara ward	Afijio	4	445.1 78.2 1963.1 26860.2	T.S W.L F.L F.B	1.7 9.1 16.2 -	1.7 7.4 7.1 -	HA
3	Farm settlement area	Afijio	4	157.5 72.0 13274.0 1052.2	T.S W.L F.L F.F.B	1.5 5.0 28.1 -	1.5 3.5 23.1 -	HK
4	Fiditi ward I	Afijio	4	469.2 110.6 778.4 1030.5	T.S W.L F.L F.B	1.1 12.3 40.7 -	1.1 11.2 28.4 -	HA
5	Fiditi ward II	Afijio	3	2964.7 79.8 1333.5	T.S W.L F.L	0.7 10.5 -	0.7 11.2 -	H
6	Odofin Awe ward	Afijio	3	521.1 244.9 918.7	T.S W.L F.L	1.0 15.7 -	1.0 14.7 -	H
7	Oniyere Village Awe ward	Afijio	4	110.9 374.9 666.5 5763.4	T.S W.L F.L F.B	0.5 41.6 56.8 -	0.5 41.4 14.9 -	HA
8	Akinmorin Jobele Ward	Afijio	4	754.0 146.4 950.7 1119.3	T.S W.L F.L F.B	2.1 13.6 40.7 -	2.1 11.5 27.1 -	HA
9	Iware ward	Afijio	4	1151.3 55.9 6920.8 877.0	T.S W.L F.L F.F.B	0.9 3.6 26.6 -	0.9 2.6 23.1	HK
10	Imini ward	Afijio	4	2170.5 142.4	T.S W.L	1.0 10.5	1.0 9.5	HK

				1022.7 694.3	F.L F.F.B	39.2 -	28.7 -	
11	Oke afin	Atiba	4	1405.2 524.1 1187.8 1668.2	T.S W.L F.L F.B	1.6 12.2 46.4 -	1.6 10.7 34.1 -	HA
12	Lagbodoko	Atiba	4	240.7 44.2 9424.5 384.4	T.S W.L F.L F.F.B	1.3 7.4 26.9 -	1.3 6.1 19.4 -	HK
13	Aremo m.t.d. police station	Atiba	4	1768.3 56.8 303.6 222.8	T.S W.L F.L F.F.B	0.6 4.6 19.2 -	0.6 4.0 14.6	HK
14	Odejin area	Atiba	4	118.9 166.3 691.1 588.5	T.S W.L F.L F.F.B	2.2 18.1 50.2 -	2.2 15.9 32.1 -	HK
15	Oke olola-aladoota	Atiba	4	1157.2 247.7 916.8 2454.8	T.S W.L F.L F.B	1.4 30.4 52.0 -	1.4 29.0 21.5 -	HA
16	Omo-Oba/Agunpopo	Atiba	3	5365.5 147.8 1006.3	T.S W.L F.B	0.9 3.1 -	0.9 2.2 -	H
17	Oke-Ebo	Atiba	4	670.4 144.6 510.1 1936.0	T.S W.L F.L F.B	1.4 10.6 46.4 -	1.4 9.2 35.7 -	HA
18	Isale Oyo	Atiba	4	5236.9 158.6 1935.3 343.0	T.S W.L F.L F.F.B	1.3 5.6 28.5 -	1.3 4.2 22.9 -	HK
19	Koso area	Atiba	4	89.4 576.7 1379.2 575.7	T.S W.L F.L F.F.B	4.2 9.8 37.7 -	4.2 5.7 27.8 -	HK
20	Elegbo area	Atiba	4	613.9 452.4 1069.8 6265.7	T.S W.L F.L F.B	0.9 6.1 33.3 -	0.9 5.3 27.2 -	HA
21	Baara	Oyo-east	4	98.0 4574.1 419.5 738.9	T.S W.L F.L F.B	3.6 13.0 48.7 -	3.6 9.4 35.7 -	QH
22	Ajagba	Oyo-east	4	271.1 80.4 744.6 913.7	T.S W.L F.L F.B	4.9 17.2 43.9 -	4.9 12.3 26.7 -	HA
23	Alodi	Oyo-east	4	1660.1 225.7 954.0 979.5	T.S W.L F.L F.B	0.8 7.3 38.1 -	0.8 6.6 31.7 -	HA
24	Apaara	Oyo-east	4	120.0 57.3	T.S W.L	3.1 7.6	3.1 4.5	HK

				1719.2 322.5	F.L F.F.B	31.9 -	24.3 -	
25	Apinni	Oyo-east	4	77.4 236.1 7910.5 256.4	T.S W.L F.L F.F.B	0.7 6.5 22.8 -	0.7 5.7 16.4 -	QH
26	Balogun	Oyo-east	4	2671.8 80.1 749.3 879.5	T.S W.L F.L F.B	1.6 4.9 37.8 -	1.6 3.3 32.9 -	HA
27	Jabata	Oyo-east	3	281.5 112.0 385.8	T.S W.L F.B	2.5 14.4 -	2.5 11.8 -	H
28	Oke-Apo	Oyo-east	4	2103.6 141.2 3980.2 1136.8	T.S W.L F.L F.F.B	0.9 6.8 36.5 -	0.9 5.9 29.7	HK
29	Oluajo	Oyo-east	4	2100.9 45.6 200.9 3164.7	T.S W.L F.L F.B	0.6 1.9 39.5 -	0.6 1.3 37.6 -	HA
30	Araromi	Oyo-east	3	493.8 165.6 1513.7	T.S W.L F.B	11.9 27.2 -	11.9 15.3 -	H
31	Akeetan	Oyo-west	3	210.0 301.2 309.4	T.S W.L F.B	0.8 37.7 -	0.8 36.9 -	A
32	Oke-Afin ward	Oyo-west	4	1126.3 206.2 2112.7 1702.1	T.S W.L F.L F.F.B	1.6 12.4 45.6 -	1.6 10.9 33.1 -	HK
33	Fasola/Soku ward	Oyo-west	4	541.2 107.4 2259.0 502.2	T.S W.L F.L F.F.B	1.7 6.8 36.5 -	1.7 5.1 29.8 -	HK
34	Iseke	Oyo-west	4	1676.6 277.8 1878.6 388.4	T.S W.L F.L F.F.B	3.7 11.7 34.8 -	3.7 8.1 23.1 -	HK
35	Ojongbodu	Oyo-west	4	176.6 273.1 864.6 976.3	T.S W.L F.L F.B	1.1 16.3 46.5 -	1.1 15.2 30.2 -	HA
36	Osokun/Cel	Oyo-west	4	5269.9 159.9 1945.9 350.3	T.S W.L F.L F.F.B	1.3 5.6 28.0 -	1.3 4.2 22.5 -	HK
37	Iyaji	Oyo-west	4	216.1 245.0 5568.0 1702.9	T.S W.L F.L F.F.B	2.0 10.3 52.8 -	2.0 8.4 42.5 -	HK
38	Opapa/Fatuk	Oyo-west	4	639.6 112.7 789.2 1695.4	T.S W.L F.L F.B	0.6 5.9 31.5 -	0.6 5.3 25.5 -	HA

39	Owode	Oyo-west	3	876.0 157.7 600.0	T.S W.L F.L	1.4 18.4 -	1.4 16.9 -	H
40	Pakoyi	Oyo-west	4	127.6 234.2 671.2 2055.9	T.S W.L F.L F.B	2.7 29.5 51.2 -	2.7 26.9 21.7 -	HA

T.S = Topsoil
W.L = Weathered Layer
F.L = Fractured Layer
F.B = Fresh Basement
F.F.B = Fairly Fresh Basement

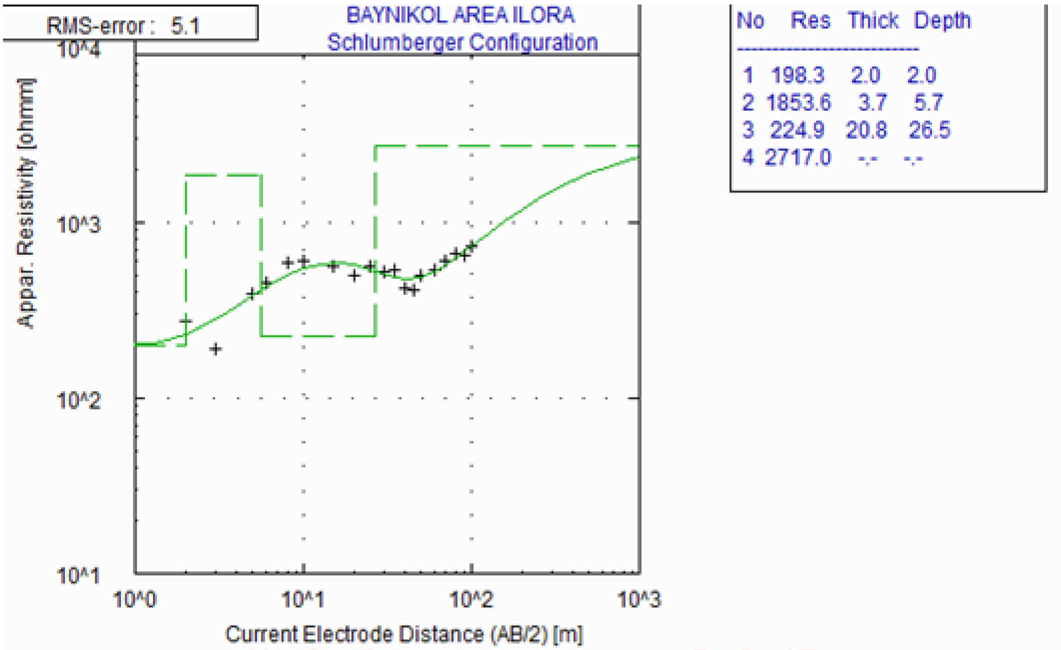

Figure 4: Resistivity sounding curve for Baynikol VES station at Afijio local government area

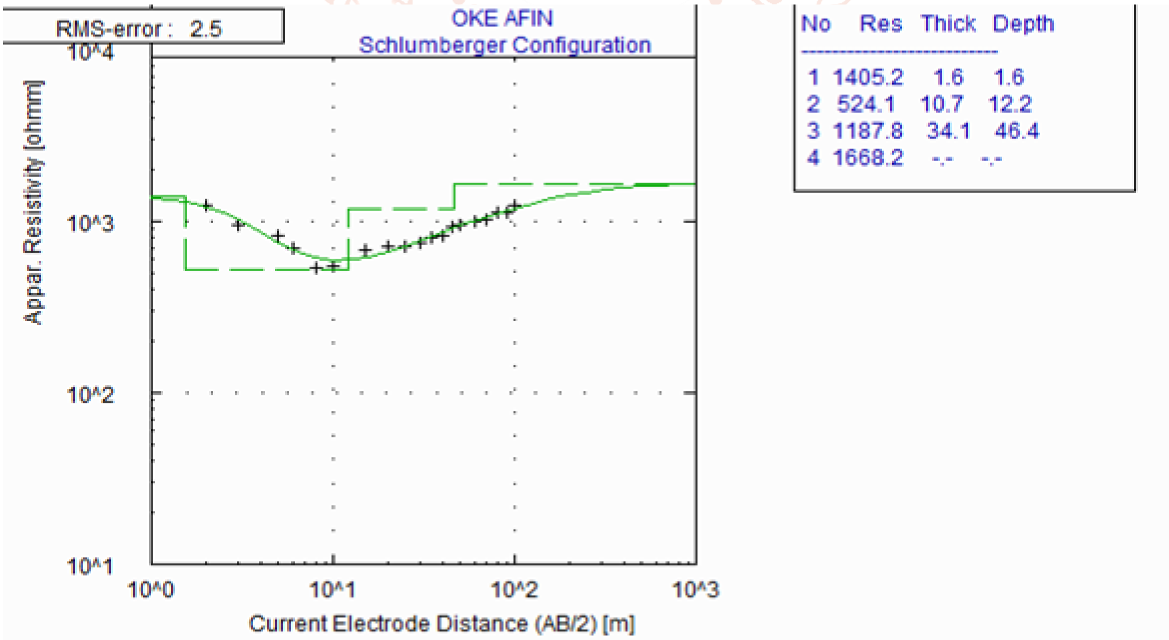

Figure 5: Resistivity sounding curve for Oke-Afin VES station at Atiba local government area

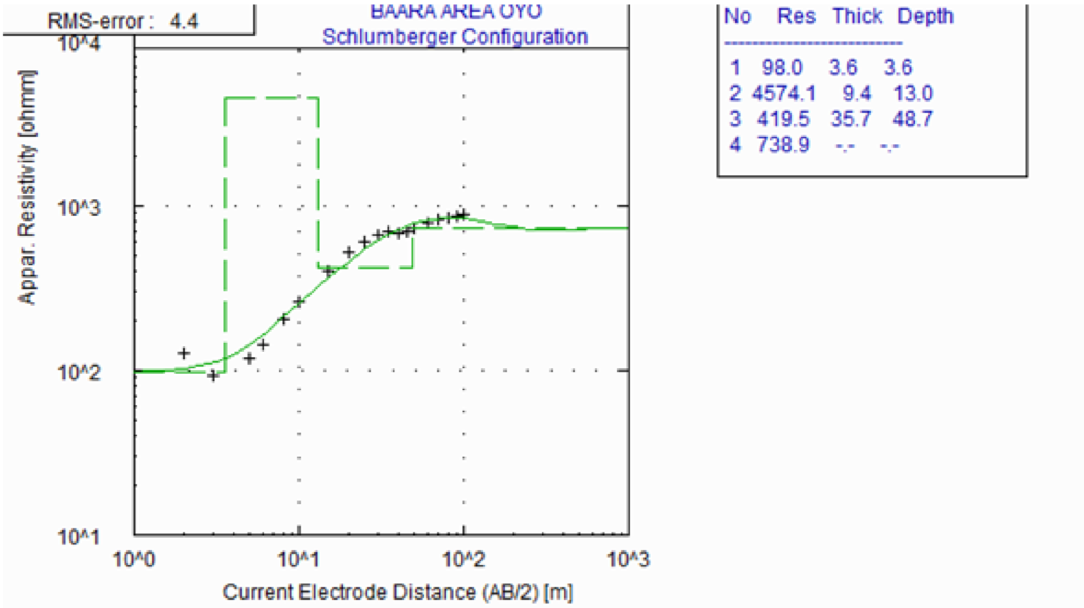

Figure 6: Resistivity sounding curve for Baara VES station at Oyo-east local government area

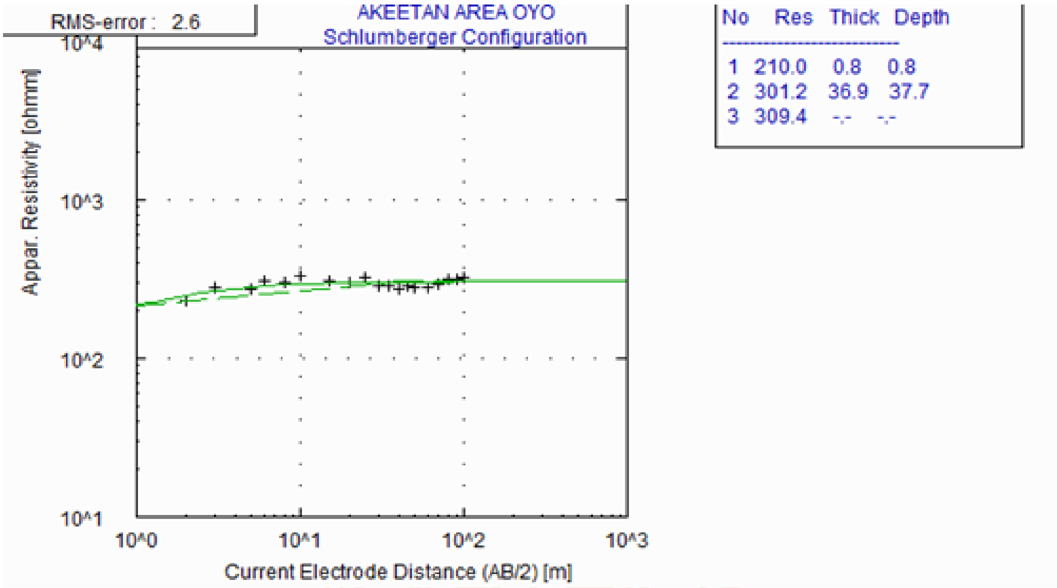

Figure 7: Resistivity sounding curve for Akeetan VES station at Oyo-west local government area

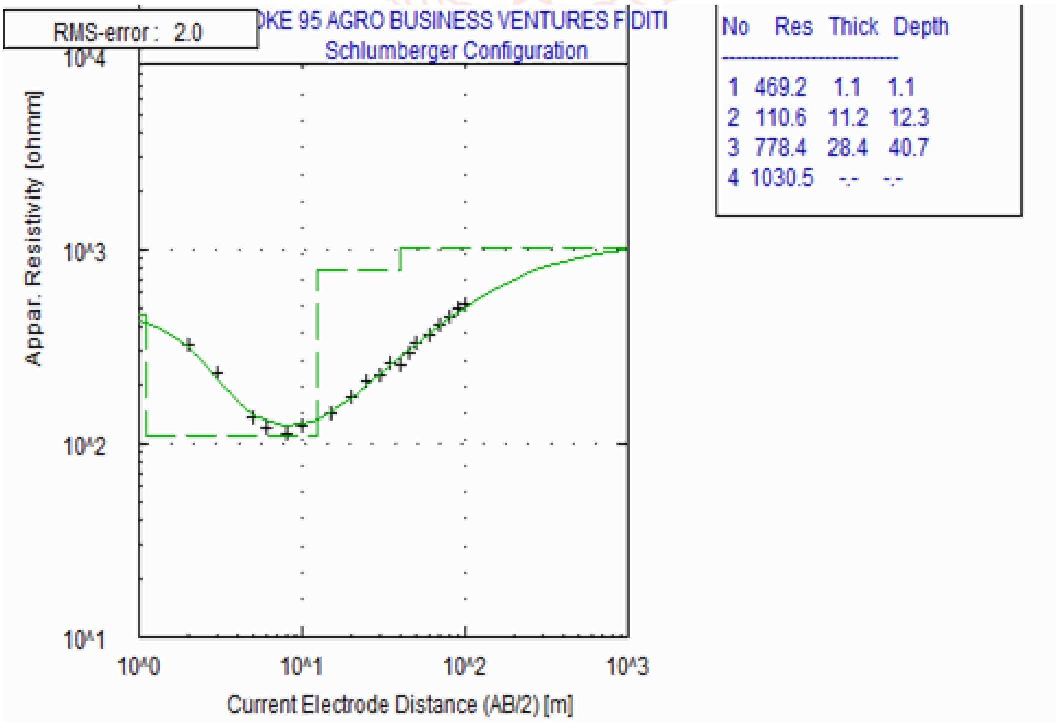

Figure 8: Resistivity sounding curve for Fiditi VES station at Afijio local government area

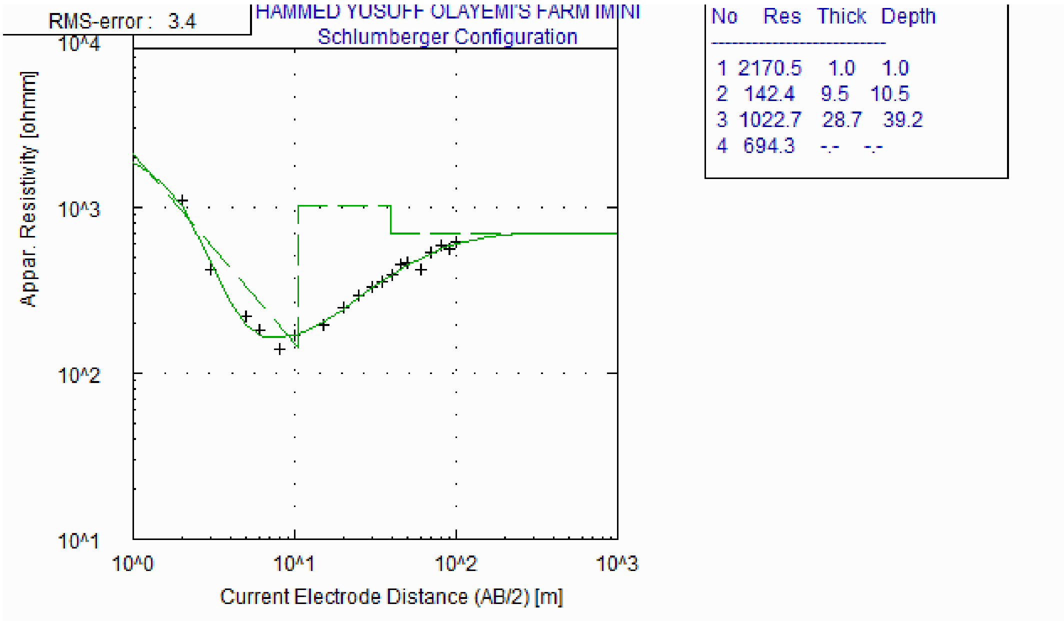

Figure 9: Resistivity sounding curve for Imini VES station at Afijio local government area

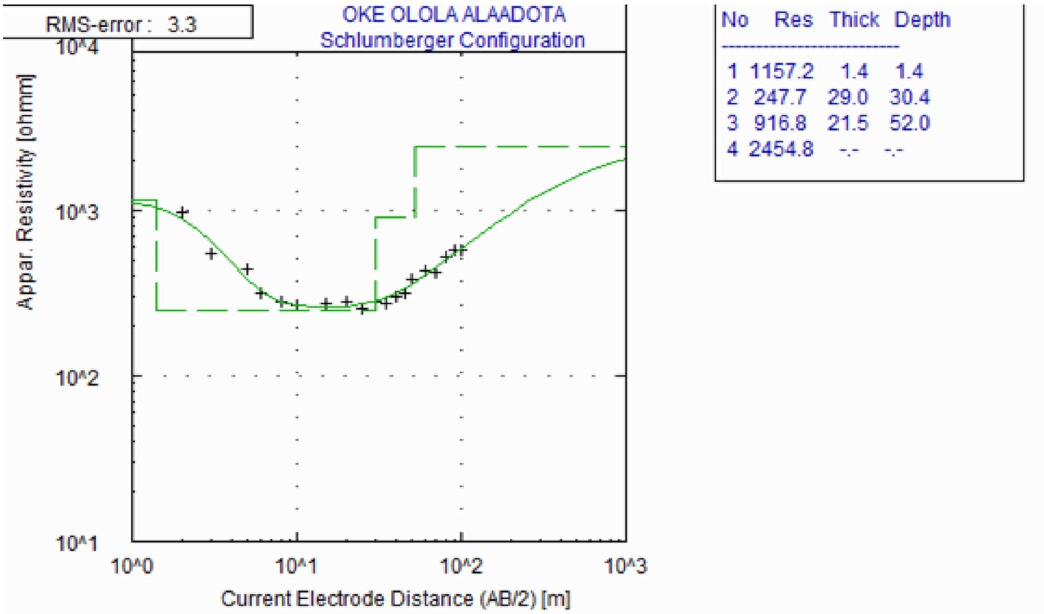

Figure 10: Resistivity sounding curve for Oke olola-Aladoota VES station at Atiba local government area

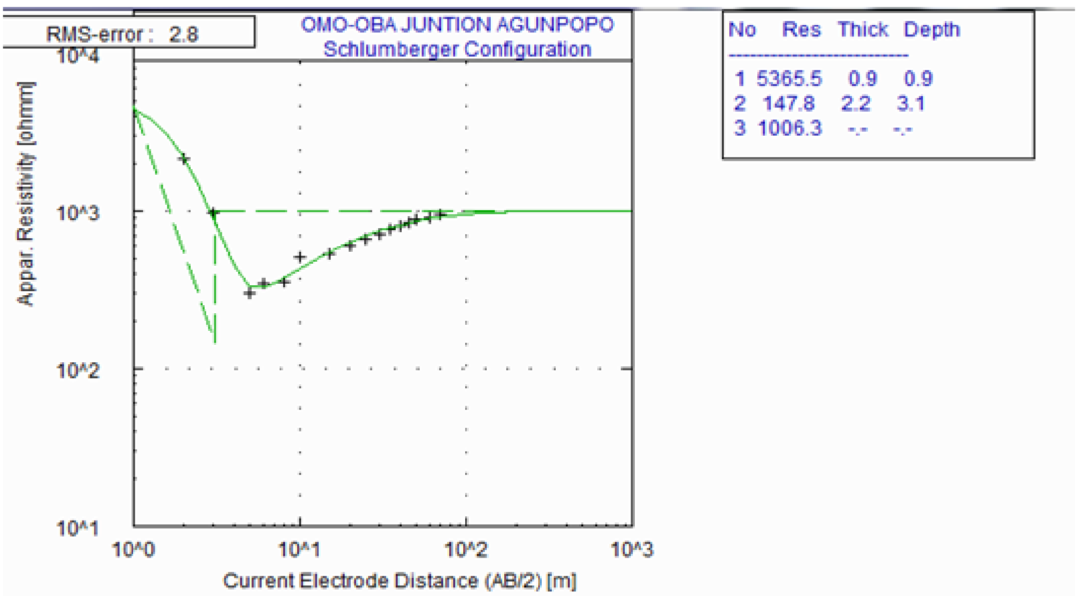

Figure 11: Resistivity sounding curve for Omo-Oba Agunpopo VES station at Atiba local government area

CONCLUSION

Hydrogeological investigation was carried out in four (4) different local government (L/G) areas which constitute part of the fourteen (14) L/G areas in Oyo federal constituency. A total of 40 vertical electrical soundings (VES) were carried out across the study areas and has contributed to the understanding of hydrogeology of the areas, the lithology of the study areas (based on the results) consist of topsoil, weathered basement, fractured basement and fresh basement. The results of the study has been able to show the locations of deep and shallow aquifers in the study areas and they are categorized into high water potential (HWP) zones and low water potential (LWP) zones. The resistivity of HWP zones are less than 400 ohmmeter while that of LWP zones are greater than 400 ohmmeter. The average thickness of the HWP in the four Local government areas is highest in Oyo-west Local government (22.7) while the average highest depth is located in Afijio Local government (22.6 m)

Some of the High water potential zones are located in communities such as Lagbodoko (6.1 m thick, 7.4 m deep), Oke-Olola (29.0 m thick, 30.4 m deep), Aremo (14.6 m thick, 19.2 m deep), in Atiba local government (L/G)t area. Oniyere (41.4 m thick, 41.6 m deep), in Afijio L/G area. Akeetan (36.9 m thick, 37.7 m deep) and Oluago on Oyo-east L/G area (37.6 m thick, 39.5 m deep). The lower potential zones are located at VES station Baynikol in Afijio L/G area, Oke-Afin, Koro and Elegbo in Atiba L/G area; Baraa in Oyo-east local government area. The results of this investigation has provided additional information to any individual intending to solve the groundwater problems.

REFERENCES

[1] M.B. Aminu, C.A. Nanfa, J.I. Hassan, I. Yahuza, S.D. Christopher, and G.O. Aigbadon. "Application of Electrical Resistivity for Evaluation of Groundwater Occurrence within Adankolo Campus and Environs, Lokoja North Central, Nigeria". European Journal of Environment and Earth Sciences, 3 (2022) 1:14-22.

[2] J.P. Allen, E.A. Atekwana, J.W. Duris, D.D. Werkema, and S. Rossbach. "The microbial community structure in petroleum-contaminated sediments corresponds to geophysical signatures". Appl. Environ. Microbio. 73 (2007) 2860–2870.

[3] J.M. Thabit, and M.M. AL-Hameedawie. "Delineation of groundwater aquifers using VES and 2D imaging techniques in north Badra area, eastern Iraq". Iraqi J. Sci. 55 (2014) 174–183.

[4] F. H. Al-Menshed and J. M. Thabit. "Comparison between VES and 2D imaging techniques for delineating subsurface plume of hydrocarbon contaminated water southeast of Karbala city, Iraq". Arabian J. Geosci. 11 (2018) https://doi.org/10.1007/s12517-018-3479-5

[5] S.M. Sharafeldin, K.S. Essa, M.A.S. Youssef, H. Karsli, Z.E. Diab and N Sayil. "Shallow geophysical techniques to investigate the groundwater table at the Great Pyramids of Giza, Egypt." Geosci. Instrument. Method. Data Syst.8 (2019) 29–43.

[6] J. G. Griffths. Mapping in engineering geology. Geological society of London (2002)

[7] K. Dahab, A. Sewidan, and A. Shedid. "Infiltration capacity and ground water potentiality of Hurghada area, Red Sea Egypt". Proc 3rd inter conference Geo Africa, faculty of science, 2. Assiut university, Egypt, (2003). 65–91.

[8] A. G. Hewaidy, E. A. El-Motaal, S. A. Sultan, T. M. Ramdan, A. A. El Khaff, S. A. soliman. "Groundwater exploration using resistivity and magnetic data at the northwestern part of the Gulf of Suez., Egypt". Egypt. J. Pet. 24 (2015) 255–263. Https://doi. Org/10.1016/j.ejpe.2015.07.010.

[9] S.A. Araffa, H.S. Sabet, and W.R. Gaweish. "Integrated geophysical interpretation for delineating the structural elements and groundwater aquifers at central part of Sinai Peninsula, Egypt". J. Afr. Earth Sci. 105 (2015) 93–106. https://doi.org/10.1016/j.jafrearsci.2015.02.011.

[10] E.S. Selim, O. Abdel-Raouf and M. Mesalam. "Implementation of magnetic, gravity and resistivity data in identifying groundwater occurrences in El Qaa Plain area, Southern Sinai, Egypt". J. Asian Earth Sci. 128 (2016) 1–26. https://doi.org/10.1016/j.jseaes.2016.07.020.

[11] D.O. Boubaya, "Combining resistivity and aeromagnetic geophysical surveys for groundwater exploration in the maghnia plain

of Algeria". J. Geol. Res. (2017) 1–14. https://doi.org/10.1155/2017/1309053

[12] J. A. Olatunji, O. V. Omonona and O. A. Odediran. "Electrical resistivity investigation of the groundwater potential in parts of kwara state polytechnic, Ilorin, Nigeria". Global Journal of Pure and Applied Sciences 23 (2017) 157-166.

[13] S.A. Araffa, M.I. Mohamadin, H. Saleh Sabet, and M.S. Takey. "Geophysical interpretation for groundwater exploration around Hurghada area, Egypt". NRIAG J. Astron. Geophys. 8 (2019) 171–179. https://doi.org/10.1080/20909977.2019.1647389.

[14] E. Joel, P. Olasehinde, T. Adagunodo, M. Omeje, M. Akinyemi, and J. Ojo. "Integration of aeromagnetic and electrical resistivity imaging for groundwater potential assessments of coastal plain sands area of Ado-Odo/Ota in southwest Nigeria". Groundwater Sustain. Dev. 9 (2019) 100264 https://doi.org/10.1016/j. gsd.2019.100264.

[15] R. Stanly, S. Yasala, R.V. Murugesan. "Hydrological subsurface investigation using geophysical electrical and magnetic methods in and around Valliyar river basin, India". Results in Geophysical Sciences 7 (2021) 100022

[16] G. C. Ufoegbune, O. C. Oparinde, A. O. Eruola. "Municipal water supply planning in Oyo metropolis, Oyo state, south western Nigeria". Journal of Geography and Regional Planning 4 (2011) 7: 392-400.

[17] J.O. Ayoade,. "Tropical Hydrology and Water Resources", Macmilan, Nigeria (1988).

[18] H. Solihu and S.O. Bilewu. "Availability, coverage, and access to the potable water supply I Oyo state Nigeria". Environmenta Challenges 5 (2021). 1-10.

[19] A. A. Elueze, B. E. Ephraim, M. E. Nton. "Hydrochemical assessment of surface water in part of southeastern Nigeria". Mineral Wealth, 119 (2001a) 45 – 58.

[20] A.A. Elueze. "*Geology of the Precambrian Schist Belt in Ilesha Area, Southwestern Nigeria*"; Ward, S.H., Ed.; Geological Survey of Nigeria (1988) 77–82.

[21] M.A. Rahaman. "*Recent Advances in the Study of the Basement Complex of Nigeria*". Ward, S.H., Ed.; Geological Survey of Nigeria: Kaduna, Nigeria, (1988) 11–41.

[22] A.K. Olawuyi, and S.B. Abolarin. "Evaluation of vertical electrical sounding method for groundwater development in basement complex terrain of West-central Nigeria". Nigerian Journal of Technological Development. Vol. 10 (2013) 2: 22-28.

[23] P.V. Sharma. "Environmental and engineering geophysics. Cambridge university press, Cambridge", (1997) 1-475. Http://dx.doi.org/10.1017/cbo9781139171168.002

[24] L. Abudulawal, S. A. Amidu, K. A. Apanpa, O. A. Adeagbo, O. A. Akinbiyi. "Geophysical investigation of subsurface water of Erunmu and its environs, southwestern Nigeria using electrical resistivity method". Journal of Applied Sciences 15 (2015) 5:741-752.

[25] K.E. Aweto. "Resistivity methods in hydro-geophysical investigation for groundwater in Aghalokpe, Western Niger Delta". Global Journal of Geological Science, 11 (2013) 47-55.

[26] J.A. Olatunji, O.V. Omonona, and O.A. Odediran. "Electrical resistivity investigation of the groundwater potential in parts of Kwara state polytechnic, Ilorin, Nigeria". Global Journal of Pure and Applied Sciences. 23 (2017) 157-166.

[27] S.A. Adekoya, J.O. Coker, H.T. Oladunjoye, and O.A. Adenuga. "Aquifer characterization of some parts of Ijebu Igbo using electrical resistivity methods", IOP Conf. Series: Journal of Physics: Conf. Series 1299. (2019) 012075 doi:10.1088/1742-6596/1299/1/012075

[28] C.C. Nwachukwu, C.C. Ugbor, O.J. Ogboke. "Electrical Resistivity Sounding for Groundwater Investigation around Enugu Metropolis and the Environs, Southeast Nigeria". International Journal of Geosciences. 13 (2022) 54-70. DOI: 10.4236/ijg.2022.131004

[29] B.S, Jatau, N.O. Patrick,A. Baba, S.I. Fadele,. "The use of Vertical electrical sounding for subsurface geophysical investigation around Bomo area, Kaduna state, Nigeria". IOSR Journal of Engineering. 3 (2013) 1: 10-15.

[30] P. Okafor, and L. Mamah. "Integration of geophysical techniques for groundwater

potential investigation in Katsina-Ala, Benue state, Nigeria". The Pacific Journal of Science and Technology. 13 (2012) 2: 463-474.

[31] A.E. Adeniji, D.N. Obiora, O.V. Omonona, andR. Ayuba. "Geo-electrical evaluation of groundwater potentials of Bwari basement area, Central Nigeria". International Journal of Physical Sciences. 8 (2013) 25:1350-1361.

[32] O. Abiola, T.H.Ogunribido, B.A. Omoniyi, and O. Ikue pamitan. "Geo-electric assessment of groundwater prospect in supare estate, supare Akoko, southwestern Nigeria". Geosciences, 3 (2013) 1:23-33.

[33] O.C. Coker. "Vertical electrical soundings methods to delineate potential groundwater aquifers in Akobo area, Ibadan, southwestern Nigeria". Journal of Geology and Mining Research. 4 (2012) 2:35-42.

[34] V.I. Obianwu, O.E. Atan, A.A. Okiwelu. "Determination of aquifer position using geophysical method". Applied Physics Research Vol. 7 (2015) 2: 83-92.

[35] A.E.Edet, T.N. Nganje, A. J.Ukpong, and A.S. Ekwere. "Groundwater chemistry and quality of Nigeria ": A Status Review. African Journal of Environmental Science and Technology, 5 (2011) 13:1152-1169.

[36] A.E. Akpan, A.N. Ugbaja, and N.J. George. "Integrated geophysical, geochemical and hydrogeological investigation of shallow groundwater resources in parts of Ikom-Mamfe Embayment and the adjourning in Cross River State, Nigeria". Environ. Earth Sci. (2013) http://dx.doi.org/10/1007/s12665-013-2232-3.